10.8 BCD Proposal: Controls-Instrumentation Integration

1. Introduction and Scope of System Integration

Definitions:

Beam Instrumentation: All Instruments in the ILC accelerator complex, which measure beam related parameters, i. e. intensity, position, emittance, etc. The core data and the control of the instrument has to be handled by the control system. Some instruments may also be part of a feedback system.

Control System: Remotely handles *all* systems and data in the ILC accelerator complex, including the beam instruments. We may define the accelerator-wide distributed *control data bus* -e. g. a standard Ethernet-based multi-gigabit serial network -as the distributed I/O-interface of the control system, which connects to all instrument modules.

In this subtopic we limit the scope of the integration into controls to beam instrumentation devices, i. e. beam monitors. At a later state one may/should extend the scope to general instrumentation and related topics, like LLRF and instrumentation of cryogenics, vacuum, magnet PS, etc. While the new developments and discussions on advanced ILC beam monitors mostly focuses on beam pickup physics and signal detection techniques, this paragraph tries to cover data acquisition (DAQ) and control aspects in a common way, applicable for most of the ILC beam instrumentation.

Concerning data acquisition aspects we can divide the ILC sub-accelerators into:

Linac: Injectors, Main Linacs and Beam Delivery System (BDS), including bunch compressors, spin rotators, etc., i.e. all straight sub-accelerators. Here the beam is present at the 200 ms repetition rate and has its nominal bunch-to-bunch spacing (~ 300 ns). Nearly all Linac beam instruments acquire their data on a bunch-by-bunch basis, identifying each bunch in the bunch-train.

Damping Rings (DR): Here the beam has a compressed bunch spacing, 6...20 ns. For most beam instruments (some exceptions) a turn-by-turn, or even slower data acquisition is sufficient, which relaxes DAQ and integration requirements. On the other hand a BPM-based, fast global orbit feedback system has to be established to minimize the beam emittance.

Major, high quantity ILC beam instrumentation systems are:

Beam Position Monitors (BPM): Data and control of about 2000 Linac and 800 DR BPM's has to be handled. The BPM's are distributed everywhere along the ILC accelerator complex. Also a fraction of the 20000 HOM-coupler signals might be equipped with read-out hardware. Some BPM's are dedicated for the machine protection system (MPS), others are part of feedback-loops.

Beam Intensity Monitors (Toroids, WCM): 50-100 toroids and wall current monitors are used to measure the bunch charges along the ILC accelerator complex.

Beam Loss Monitors (BLM): 100-500 ionization chamber BLM's are distributed to check and minimize beam losses.

Other beam instruments (beam phase, transverse and longitudinal beam/bunch profile) are of more complex and dedicated character.. The number of these systems is smaller, some are combined within a special *diagnostic section.*

The beam instrumentation integration efforts has to focus on the major components, i. e. BPM systems, without excluding the integration of new "exotic" instruments. This is particular important, as ILC beam monitors will be developed at different institutes, universities and industries all over the planet. The system integration has to be of open architecture and expandable to include other ILC subsystems, e. g. LLRF.

2. Example of the Linac BPM System Integration

Fig. 1 gives an example of the required hardware, which integrates a single Linac BPM into the control system. The 2-tunnel solution prefers minimum or no (radiation tolerant) hardware in the accelerator tunnel, so only the BPM pickup (RF BPM) is located here. Coaxial cables connect through links every 40 m to the electronics hardware in the support tunnel. This read-out and control system splits into two parts:

Dedicated Analog Hardware: An instrument specific signal processing interface.

Common Digital Hardware: A common, versatile digital DAQ and control platform.

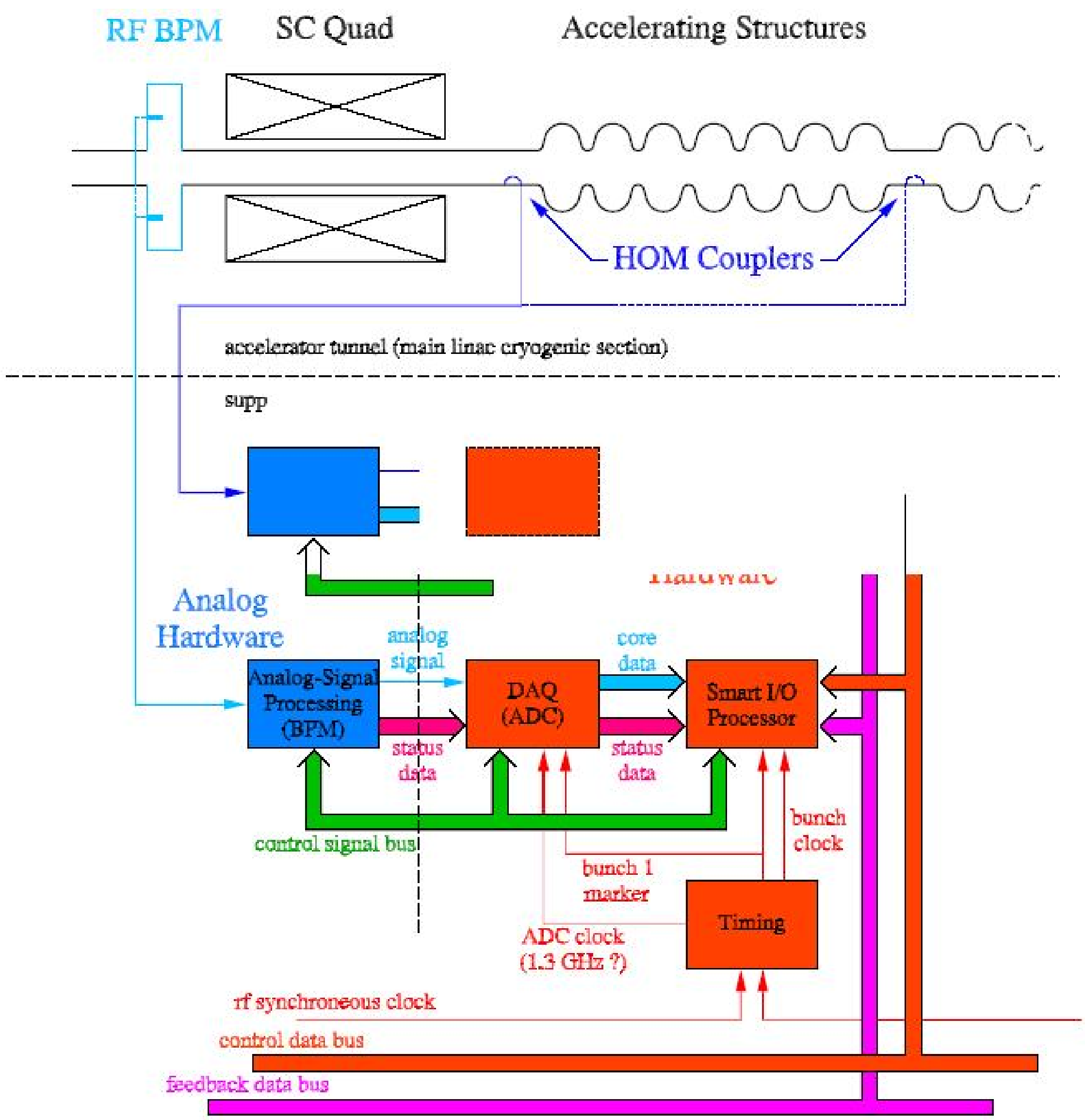

Figure 1: Example of the Linac BPM Hardware

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To acquire bunch-by-bunch data a timing module is required, which references to the phase stable 1.3 GHz RF signal. Signals derived by this timing board include marker signals (bunch # 1 -based on the time, fiducial of the timing distribution system -and ticks at every bunch), as well as ADC clock signals. The analog bunch signals are acquired with a high sample rate, e. g. rf synchronous at 1.3 GHz. F\1rther digital signal processing provides an entry of *physical* data, including all required calibrations and normalizations for each bunch. Beside this core data processing, the integration platform has to handle instrument status data and control information. A smart I/O processor feeds the information on the control data bus for shipment to the control room, as well as to other systems if required. Within the 200 ms repetition rate all the acquired data of up to 8000 bunches has to be send through the control data bus. Some beam monitors may required a dedicated, faster *feedback data bus*, which has to send data within a fraction of the 1 ms macropulse duration.

The electro-mechanics (crates, racks, PS, ...) and interfaces have to be specified. Beside the upcoming high availability ATCA standard, also traditional standards (VME, VXI, PXI, etc.) and custom solutions have to be considered. While there is a high availability demand for systems like modulators, magnet power supplies, RF, etc., redundancy is a build-in feature into many beam instrumentation systems, like BPM's, which relaxes redundancy/hot-swap needs on the hardware side. However, it is highly desirable to have a uniform hardware-software platform and interface for instrumentation wherever possible throughout the ILC.

3. Present State-of-the-Art

3.1 Key Components

Key hardware components in the common digital part of Fig. 1 are fast analog-to-digital converters (ADC), field-programmable gate-arrays (FPGA) and digital signal processors (DSP). Table 1 list current (End 2005) state-of-the-art ADC technology. Top-of-the-line FPGA's and DSP's have similar characteristics, or can parallel process ADC data. While the characteristics of these components will improve over the next years and prices will decrease -not every kind of beam instrumentation DAQ needs the maximum speed or band- width performance. Compatible ADC mezzanine boards within the DAQ section will handle the different demands.

Company	Type	Resolution (Bits)	Sampling Rate	Analog Bandwidth
National Semiconductor	ADC08D1500	2 x 8	3 GSPS	1.7 GHz
Atmel	TS83102G0BMGS	10	2 GSPS	3.3 GHz
Anlaog Devices	AD12500	12	500 MSPS	?
Texas Instruments	ADS5500	14	125 MSPS	750 MHz
Linear Technology	LTC2208	16	130 MSPS	700 MHz

Table 1: State-of-the-Art ADC's, 2005

3.2 System Integration

Most of the current integration developments, regarding linear collider instrumentation, are done at the TESLA Test Facility (TTF) at DESY [1] (more information at *http://tesla.desy.de/dQocs/doocs.html).*

Their data acquisition system is based on a in-house developed VME 8-channel ADC board (14-bit, 10MSPS), capable of acquiring synchronous bunch-by-bunch data of the whole accelerator complex for 1 *μs* spaced bunches (only 1 sample per bunch). At the Spallation Neutron Source (SNS) multi-lab integration experience has been gained, not limited to beam instrumentation [2]. Here a commercial PC/PCI platform defines the hardware integration standard.

4. Path to Specification and Future R&D Requirements

At present the ILC system integration requirements are not fully specified, except we should try to be able to integrate all different kind of (beam) instrumentation:

1. Standard beam monitors (BPM, BLM, toroids, beam phase monitors)
2. Complex beam monitors systems (Laser wire scanners, longitudinal bunch profile monitors)
3. "Exotic" and experimental beam monitors from universities and collaborators

Many requirements, like bandwidth, hardware and software standards, etc. still have to be established. Technical aspects of the integration activities may change, dictated by new technology achievements in the communications industry.

Present and upcoming ILC Test Facilities (TTF, ATF, SMTF,...) are the preferred environment to develop and test future R&D integration efforts. These test accelerators have requirements and demands similar to the ILC, but obviously on a smaller scale.

5. References

[1] A. Agababyan, et. al.; *Integrating a Fast Data Acquisition System into* the *DOOCS Control System;* ICALEPCS2005, Geneva, Switzerland.

[2] D. P. Gurd, et. al.; *First Experience with Handover and Commissioning of* the *SNS Control System;*

ICALEPCS2003, Gyeongju, Korea.